CLAIMS:

What is claimed is:

1. A method of operating an implantable medical device comprising a plurality of leads and an implantable medical device circuit enclosed within a hermetically sealed housing in relation to cardiac mechanical function of a first heart chamber during a heart cycle comprising:

implanting a first lead bearing a first sonomicrometer crystal at a first location of the heart outside the first heart chamber;

implanting a second lead bearing a second sonomicrometer crystal at a second location of the heart outside the first heart chamber, whereby the first and second locations define a vector across and through a substantial portion of the first heart chamber;

coupling the first and second leads to the implantable medical device circuit and implanting the housing in the patient, and

operating the implantable medical device by:

during one or more heart cycle, periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal;

determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal; and

adjusting the operation of the implantable medical device as a function of the determined distances between the first and second sonomicrometer crystals during a heart cycle.

2. The method of Claim 1, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

delivering a pacing pulse to the first heart chamber to elicit a contraction of the first heart chamber;

and wherein the adjusting step comprises adjusting a parameter of the delivered pacing pulse as a function of the determined distance between the first and

second sonomicrometer crystals during a heart cycle following delivery of a pacing pulse.

3. The method of Claim 1, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

delivering a pacing pulse to the first heart chamber to elicit a contraction of the first heart chamber; and wherein:

the determining step further comprises determining if a series of distances measured during the determining step represents a contraction of the first heart chamber; and

the adjusting step comprises adjusting the pacing energy of succeeding delivered pacing pulses to a pulse energy sufficient to elicit the contraction of the first heart chamber upon delivery of each pacing pulse.

4. The method of Claim 1, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

delivering pacing pulses to the first heart chamber at a predetermined pacing rate to elicit contractions of the first heart chamber; and wherein:

the determining step further comprises determining if the distance measured during the determining step represents a contraction of the first heart chamber; and

the adjusting step comprises adjusting the pacing rate of succeeding delivered pacing pulses to a pacing rate sufficient to elicit the contraction of the first heart chamber upon delivery of each pacing pulse.

5. The method of Claim 1, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

delivering pacing pulses to the first heart chamber at a predetermined pacing rate to elicit contractions of the first heart chamber; and wherein:

the determining step further comprises measuring the contractility of the first heart chamber as a function of the distances measured during the determining step; and

the adjusting step comprises adjusting the pacing rate of succeeding delivered pacing pulses to a pacing rate that is proportional to the measured contractility sufficient to maximize the contractility of the first heart chamber upon delivery of each pacing pulse.

6. The method of Claim 1, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

operating a sense amplifier of the implantable pacing system to sense electrical activity of the first heart chamber accompanying a contraction of the first heart chamber and to provide a sense event signal; and wherein:

the determining step further comprises identifying a contraction of the first heart chamber as a function of the distances measured during the determining step; and

the adjusting step comprises one of increasing the sensitivity of the sense amplifier or providing a sense event signal in the event that the sense amplifier does not provide a sense event signal when a contraction is identified as a function of the determined distance between the first and second sonomicrometer crystals during a heart cycle.

7. The method of Claim 1, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

operating a sense amplifier of the implantable pacing system to sense electrical activity of the first heart chamber accompanying a contraction of the first heart chamber and to provide a sense event signal; and wherein:

the determining step further comprises identifying a first heart chamber contraction of the first heart chamber as a function of the distances measured during the determining step; and

the adjusting step comprises one of decreasing the sensitivity of the sense amplifier or ignoring the sense event signal in the event that the sense amplifier provides a sense event signal but a contraction is not identified as a function of the determined distance between the first and second sonomicrometer crystals during a heart cycle.

8. The method of Claim 1, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

delivering first and second pacing pulses separated in time by a pace delay to the first and second heart chambers, respectively, wherein the first and second heart chambers are right and left heart chambers, to elicit synchronized contractions of the first and second heart chambers; and

wherein the adjusting step comprises adjusting the timing of delivery of the first and second pacing pulses as a function of the determined distances between the first and second sonomicrometer crystals during a heart cycle following delivery of first and second pacing pulses to maximize the value of a weighted combination of the systolic shortening of the RV-LV distance and the inverse of the end diastolic distance for a given heart rate.

9. The method of Claim 1, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

delivering a first pacing pulse to the left ventricle and a second pacing pulse to the right ventricle separated in time by a V-V pace delay to elicit synchronized contractions of the right and left ventricles; and

wherein the adjusting step comprises adjusting the V-V pace delay as a function of the determined distance between the first and second sonomicrometer crystals to maximize the value of a weighted combination of the systolic shortening of the RV-LV distance and the inverse of the end diastolic distance for a given heart rate.

10. The method of Claim 1, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

delivering a first pacing pulse to the atria and a second pacing pulse to the ventricles separated in time by an AV delay to elicit synchronized contractions of the atria and ventricles; and

wherein the adjusting step comprises adjusting the AV delay as a function of the determined distance between the first and second sonomicrometer crystals to maximize the value of a weighted combination of the systolic shortening of the RV-LV distance and the inverse of the end diastolic distance for a given heart rate.

11. The method of Claim 1, wherein the implantable medical device comprises an anti-tachyarrhythmia control device for delivering a therapy in response to detection of a tachyarrhythmia of the first heart chamber, and the adjusting step comprises processing the determined distances to detect a tachyarrhythmia of the first heart chamber.

12. The method of Claim 1, wherein the implantable medical device comprises an anti-tachyarrhythmia control device for delivering a therapy in response to detection of a tachyarrhythmia of the first heart chamber, and further comprising:

operating a sense amplifier of the implantable anti-tachyarrhythmia control device to sense electrical activity of the first heart chamber to provide sense event signals;

processing the sense event signals in relation to tachyarrhythmia detection criteria; and

provisionally declaring a tachyarrhythmia state of the first heart chamber when the processed sense event signals satisfy tachyarrhythmia detection criteria;
and wherein:

the determining step further comprises determining the strength of contractions of the first heart chamber as a function of the distances measured during the determining step; and

the adjusting step comprises confirming the tachyarrhythmia state in the event that the strength of contractions is decreased below a predetermined value.

13. The method of Claim 1, wherein the implantable medical device comprises an anti-tachyarrhythmia control device for delivering a therapy in response to detection of a tachyarrhythmia of the first heart chamber, and further comprising:

operating a sense amplifier of the implantable anti-tachyarrhythmia control device to sense electrical activity of the first heart chamber to provide sense event signals;

processing the sense event signals in relation to tachyarrhythmia detection criteria; and

declaring a tachyarrhythmia state of the first heart chamber when the processed sense event signals satisfy tachyarrhythmia detection criteria;
and wherein:

the determining step further comprises determining the strength of contractions of the first heart chamber as a function of the distances measured during the determining step; and

the adjusting step comprises selection or delivery of either burst anti-tachycardia pacing or electrical cardioversion/defibrillation shock depending on the strength of contractions of the first heart chamber.

14. The method of Claim 1, wherein the implantable medical device comprises an anti-tachyarrhythmia control device for delivering an anti-tachyarrhythmia therapy in response to detection of a tachyarrhythmia of the first heart chamber, and wherein:

the step of periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal is undertaken after delivery of an anti-tachyarrhythmia therapy;

the step of determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal is undertaken after delivery of the anti-tachyarrhythmia therapy; and
further comprising:

operating a sense amplifier of the implantable anti-tachyarrhythmia control device to sense electrical activity of the first heart chamber to provide sense event signals after delivery of the anti-tachyarrhythmia therapy; and

determining the efficacy of the delivered anti-tachyarrhythmia therapy as a function of the determined distances between the first and second sonomicrometer crystals in the presence or absence of sense event signals, whereby one of successful termination of the tachyarrhythmia is determined, resumption of the tachyarrhythmia is determined requiring delivery of a further anti-tachyarrhythmia therapy is delivered, or pulse less electrical activity is determined, whereby a further electrical

stimulation therapy is delivered to strengthen mechanical contraction of the first heart chamber.

15. A method of operating an implantable medical device in relation to cardiac mechanical function of a first heart chamber during a heart cycle comprising:

implanting a first lead bearing a first sonomicrometer crystal at a first location of the heart outside the first heart chamber;

implanting a second lead bearing a second sonomicrometer crystal at a second location of the heart outside the first heart chamber, whereby the first and second locations define a vector across and through a substantial portion of the first heart chamber; and

coupling the first and second endocardial leads to an implantable medical device, and operating the implantable medical device by:

during one or more heart cycle, periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal;

determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal; and

deriving and storing data representing one or more of contractility and cardiac output of the first heart chamber from the determined distances in the implantable medical device.

16. The method of Claim 15, wherein the implantable medical device comprises a therapy delivery system, and further comprising:

delivering a therapy to the first heart chamber as a function of one or more of contractility and cardiac output of the first heart chamber.

17. The method of Claim 16, further comprising adjusting the operation of the implantable medical device as a function of the determined distances between the first and second sonomicrometer crystals during a heart cycle.

18. A method of operating an implantable medical device comprising a plurality of leads and an implantable medical device circuit enclosed within a hermetically sealed housing to determine dimensional changes or motion of a first heart chamber due to mechanical movement of the heart chamber during a heart cycle comprising:

implanting a first endocardial lead bearing a first sonomicrometer crystal through a venous pathway into a second heart chamber and disposing the first sonomicrometer crystal in association with the septum separating the first heart chamber from the second heart chamber, whereby the first sonomicrometer crystal is oriented toward but outside the first heart chamber;

implanting a second endocardial lead bearing a second sonomicrometer crystal through a venous pathway into a coronary vessel whereby the first and second sonomicrometer crystals are arranged in a vector extending through the first heart chamber;

coupling the first and second endocardial leads to the implantable medical device circuit, and operating the implantable medical device by:

during one or more heart cycle, periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal; and

at each emission during the one or more heart cycle, determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal, whereby the mechanical motion of the first heart chamber over the heart cycle can be determined without entering the first heart chamber including the wall of the first heart chamber.

19. The method of Claim 17, further comprising adjusting the operation of the implantable medical device as a function of the determined distances between the first and second sonomicrometer crystals during a heart cycle.

20. The method of Claim 18, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

providing a first pace/sense electrode on the first endocardial lead adapted to be disposed in operative relation to the second heart chamber;

providing a second pace/sense electrode on the second endocardial lead adapted to be disposed in operative relation to the first heart chamber;

delivering a pacing pulse to one of the first and second heart chambers;

adjusting a parameter of the delivered pacing pulse as a function of the determined distances between the first and second sonomicrometer crystals during a heart cycle following delivery of the pacing pulse.

21. A method of determining dimensional changes in the left ventricle due to mechanical movement of the left ventricle during the heart cycle comprising:

implanting a first endocardial lead bearing a first sonomicrometer crystal through a venous pathway with the first sonomicrometer crystal lodged within the right ventricle separated from the left ventricle by the septal wall;

implanting a second endocardial lead bearing a second sonomicrometer crystal through a venous pathway through the right atrium and the ostium of the coronary sinus such that the second sonomicrometer crystal is lodged within a coronary vessel in relation to the left ventricle whereby the first and second sonomicrometer crystals are arranged in a vector through and across a substantial portion of the left ventricle;

during one or more heart cycle, periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal; and

at each emission during the one or more heart cycle, determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal, whereby the mechanical motion of the left ventricle over the heart cycle can be determined without entering the left ventricle.

22. The method of Claim 21, further comprising the steps of:

implanting a third endocardial lead bearing a third sonomicrometer crystal through a venous pathway with the third sonomicrometer crystal is lodged in relation to one of the right atrium or the left atrium;

during one or more heart cycle, periodically energizing one of the first, second and third sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other two of the first, second. and third sonomicrometer crystals to develop ultrasonic frequency sense signals; and

at each emission during the one or more heart cycle, determining the distance between the at least one of the first and second sonomicrometer crystals and the third sonomicrometer crystal as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal, whereby the mechanical motion of the right atrium or the left atrium over the heart cycle can be determined.

23. A method of determining mechanical movement of the atria during the heart cycle comprising:

implanting a first endocardial lead bearing a first sonomicrometer crystal through a venous pathway with the first sonomicrometer crystal lodged within the right ventricle;

implanting a second endocardial lead bearing a second sonomicrometer crystal through a venous pathway with the second sonomicrometer crystal lodged in or along one of the and left right atrium, whereby the first and second sonomicrometer crystals are arranged in a vector through the one of the right and left atrium;

during one or more heart cycle, periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal; and

at each emission during the one or more heart cycle, determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal, whereby the mechanical motion of the atria can be determined.

24. A method of pacing the right and left ventricles to alleviate symptoms of heart failure comprising:

implanting a first lead bearing a first sonomicrometer crystal at a first location of the heart outside the left ventricle;

implanting a second lead bearing a second sonomicrometer crystal at a second location of the heart outside the left ventricle, whereby the first and second locations define a vector across and through a substantial portion of the left ventricle; and

coupling an implantable medical device to the first and second leads, and operating the implantable medical device by:

repetitively timing a pacing escape interval establishing paced heart cycles:

delivering a first pacing pulse to one of the right and left ventricles at the time-out of each pacing escape interval and a second pacing pulse to the other of the right and left ventricles separated in time from the first pacing pulse by a pace delay;

during one or more heart cycle, periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal;

at each emission during the one or more heart cycle, determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal, whereby the mechanical motion of the left ventricle over the heart cycle and cardiac output from the left ventricle can be assessed without entering the left ventricle; and

adjusting the pace delay to maximize the assessed cardiac output.

25. The method of Claim 24, wherein:

the implanting steps further comprise:

implanting a first endocardial lead bearing a first sonomicrometer crystal and a first pace/sense electrode through a venous pathway with the first sonomicrometer crystal lodged within the right ventricle separated from the left ventricle by the septal wall and the first pace/sense electrode situated for pacing the right ventricle; and

implanting a second endocardial lead bearing a second sonomicrometer crystal and a second pace/sense electrode through a venous pathway through the right atrium and the ostium of the coronary sinus such that the second sonomicrometer crystal is lodged within a coronary vessel in relation to the left ventricle whereby the first and second sonomicrometer crystals are arranged in a vector through and across a substantial portion of the left ventricle and the second pace/sense electrode is situated for pacing the left ventricle; and

the delivering step comprises delivering a right ventricular pacing pulse through the first pace/sense electrode and a left ventricular pacing pulse through the second pace/sense electrode.

26. The method of Claim 25 further comprising:

implanting a third endocardial lead bearing a third sonomicrometer crystal and a third pace/sense electrode through a venous pathway with the third sonomicrometer crystal lodged within the one of the right and left atria separated from the first and second sonomicrometer crystals and the third pace/sense electrode situated for pacing the one of the right and left atria; and operating the implantable medical device by:

timing the pacing escape interval as a successive V-A interval and AV delay;

delivering an atrial pace pulse through the third pace/sense electrode at the time-out of each V-A interval and the first and second pacing pulses at the time-out of the AV delay;

adjusting the AV delay to maximize the assessed cardiac output.

27. The method of Claim 24, further comprising operating the implantable medical device by:

timing the pacing escape interval as a successive V-A interval and AV delay;

delivering an atrial pace pulse to one of the right and left atria at the time-out of each V-A interval and the first and second pacing pulses at the time-out of the AV delay; and

adjusting the AV delay to maximize the assessed cardiac output.

28. An implantable medical device comprising a plurality of leads and an implantable medical device circuit enclosed within a hermetically sealed housing comprising:

a first lead bearing a first sonomicrometer crystal at a first location of the heart outside a first heart chamber and coupled to the implantable medical device circuit;

a second lead bearing a second sonomicrometer crystal at a second location of the heart outside the first heart chamber and coupled to the implantable medical device circuit, whereby the first and second locations define a vector across and through a substantial portion of the first heart chamber;

means operable during one or more heart cycle for periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal;

means for determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal; and

means for adjusting the operation of the implantable medical device as a function of the determined distances between the first and second sonomicrometer crystals during a heart cycle.

29. The implantable medical device of Claim 28, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

means for delivering a pacing pulse to the first heart chamber to elicit a contraction of the first heart chamber; and

wherein the adjusting means comprises means for adjusting a parameter of the delivered pacing pulse as a function of the determined distance between the first and second sonomicrometer crystals during a heart cycle following delivery of a pacing pulse.

30. The implantable medical device of Claim 28, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

means for delivering a pacing pulse to the first heart chamber to elicit a contraction of the first heart chamber; and wherein:

the determining means further comprises means for determining if a series of distances measured during the determining step represents a contraction of the first heart chamber; and

the adjusting means comprises means for adjusting the pacing energy of succeeding delivered pacing pulses to a pulse energy sufficient to elicit the contraction of the first heart chamber upon delivery of each pacing pulse.

31. The implantable medical device of Claim 28, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

means for delivering pacing pulses to the first heart chamber at a predetermined pacing rate to elicit contractions of the first heart chamber; and wherein:

the determining means further comprises means for determining if the distance measured during the determining step represents a contraction of the first heart chamber; and

the adjusting means further comprises means for adjusting the pacing rate of succeeding delivered pacing pulses to a pacing rate sufficient to elicit the contraction of the first heart chamber upon delivery of each pacing pulse.

32. The implantable medical device of Claim 28, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

means for delivering pacing pulses to the first heart chamber at a predetermined pacing rate to elicit contractions of the first heart chamber; and wherein:

the determining means further comprises means for measuring the contractility of the first heart chamber as a function of the distances measured during the determining step; and

the adjusting means further comprises means for adjusting the pacing rate of succeeding delivered pacing pulses to a pacing rate that is proportional to the measured contractility sufficient to maximize the contractility of the first heart chamber upon delivery of each pacing pulse.

33. The implantable medical device of Claim 28, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

means for operating a sense amplifier of the implantable pacing system to sense electrical activity of the first heart chamber accompanying a contraction of the first heart chamber and to provide a sense event signal; and wherein:

the determining means further comprises means for identifying a contraction of the first heart chamber as a function of the distances measured during the determining step; and

the adjusting means further comprises means for one of increasing the sensitivity of the sense amplifier or providing a sense event signal in the event that the sense amplifier does not provide a sense event signal when a contraction is identified as a function of the determined distance between the first and second sonomicrometer crystals during a heart cycle.

34. The implantable medical device of Claim 28, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

means for operating a sense amplifier of the implantable pacing system to sense electrical activity of the first heart chamber accompanying a contraction of the first heart chamber and to provide a sense event signal; and wherein:

the determining means further comprises means for identifying a first heart chamber contraction of the first heart chamber as a function of the distances measured during the determining step; and

the adjusting means further comprises means for one of decreasing the sensitivity of the sense amplifier or ignoring the sense event signal in the event that the sense amplifier provides a sense event signal but a contraction is not identified as a function of the determined distance between the first and second sonomicrometer crystals during a heart cycle.

35. The implantable medical device of Claim 28, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

means for delivering first and second pacing pulses separated in time by a pace delay to the first and second heart chambers, respectively, wherein the first and

second heart chambers are right and left heart chambers, to elicit synchronized contractions of the first and second heart chambers; and

wherein the adjusting means further comprises means for adjusting the timing of delivery of the first and second pacing pulses as a function of the determined distances between the first and second sonomicrometer crystals during a heart cycle following delivery of first and second pacing pulses to maximize the value of a weighted combination of the systolic shortening of the RV-LV distance and the inverse of the end diastolic distance for a given heart rate.

36. The implantable medical device of Claim 28, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

means for delivering a first pacing pulse to the left ventricle and a second pacing pulse to the right ventricle separated in time by a V-V pace delay to elicit synchronized contractions of the right and left ventricles; and

wherein the adjusting means further comprises means for adjusting the V-V pace delay as a function of the determined distance between the first and second sonomicrometer crystals to maximize the value of a weighted combination of the systolic shortening of the RV-LV distance and the inverse of the end diastolic distance for a given heart rate.

37. The implantable medical device of Claim 28, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

means for delivering a first pacing pulse to the atria and a second pacing pulse to the ventricles separated in time by an AV delay to elicit synchronized contractions of the atria and ventricles; and

wherein the adjusting means further comprises means for adjusting the AV delay as a function of the determined distance between the first and second sonomicrometer crystals to maximize the value of a weighted combination of the systolic shortening of the RV-LV distance and the inverse of the end diastolic distance for a given heart rate.

38. The implantable medical device of Claim 28, wherein the implantable medical device comprises an anti-tachyarrhythmia control device for delivering a therapy in response to detection of a tachyarrhythmia of the first heart chamber, and the adjusting means further comprises means for processing the determined distances to detect a tachyarrhythmia of the first heart chamber.

39. The implantable medical device of Claim 28, wherein the implantable medical device comprises an anti-tachyarrhythmia control device for delivering a therapy in response to detection of a tachyarrhythmia of the first heart chamber, and further comprising:

means for operating a sense amplifier of the implantable anti-tachyarrhythmia control device to sense electrical activity of the first heart chamber to provide sense event signals;

means for processing the sense event signals in relation to tachyarrhythmia detection criteria; and

means for provisionally declaring a tachyarrhythmia state of the first heart chamber when the processed sense event signals satisfy tachyarrhythmia detection criteria;

and wherein:

the determining means further comprises means for determining the strength of contractions of the first heart chamber as a function of the distances measured during the determining step; and

the adjusting means further comprises means for confirming the tachyarrhythmia state in the event that the strength of contractions is decreased below a predetermined value.

40. The implantable medical device of Claim 28, wherein the implantable medical device comprises an anti-tachyarrhythmia control device for delivering a therapy in response to detection of a tachyarrhythmia of the first heart chamber, and further comprising:

means for operating a sense amplifier of the implantable anti-tachyarrhythmia control device to sense electrical activity of the first heart chamber to provide sense event signals;

means for processing the sense event signals in relation to tachyarrhythmia detection criteria; and

means for declaring a tachyarrhythmia state of the first heart chamber when the processed sense event signals satisfy tachyarrhythmia detection criteria;

and wherein:

the determining means further comprises means for determining the strength of contractions of the first heart chamber as a function of the distances measured during the determining step; and

the adjusting means further comprises means for selection or delivery of either burst anti-tachycardia pacing or electrical cardioversion/defibrillation shock depending on the strength of contractions of the first heart chamber.

41. The implantable medical device of Claim 28, wherein the implantable medical device comprises an anti-tachyarrhythmia control device for delivering an anti-tachyarrhythmia therapy in response to detection of a tachyarrhythmia of the first heart chamber, and wherein:

the means for periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal is operated after delivery of an anti-tachyarrhythmia therapy;

the means for determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal is operated after delivery of the anti-tachyarrhythmia therapy; and

further comprising:

means for operating a sense amplifier of the implantable anti-tachyarrhythmia control device to sense electrical activity of the first heart chamber to provide sense event signals after delivery of the anti-tachyarrhythmia therapy; and

means for determining the efficacy of the delivered anti-tachyarrhythmia therapy as a function of the determined distances between the first and second sonomicrometer crystals in the presence or absence of sense event signals, whereby one of successful termination of the tachyarrhythmia is determined, resumption of the tachyarrhythmia is determined requiring delivery of a further anti-tachyarrhythmia therapy is delivered, or pulse less electrical activity is determined, whereby a further electrical stimulation therapy is delivered to strengthen mechanical contraction of the first heart chamber.

42. An implantable medical device comprising a plurality of leads and an implantable medical device circuit enclosed within a hermetically sealed housing comprising:

a first lead bearing a first sonomicrometer crystal at a first location of the heart outside a first heart chamber and coupled to the implantable medical device circuit;

a second lead bearing a second sonomicrometer crystal at a second location of the heart outside the first heart chamber and coupled to the implantable medical device circuit, whereby the first and second locations define a vector across and through a substantial portion of the first heart chamber;

means operable during one or more heart cycle for periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal;

means for determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal; and

means for deriving and storing data representing one or more of contractility and cardiac output of the first heart chamber from the determined distances in the implantable medical device.

43. The implantable medical device of Claim 42, wherein the implantable medical device comprises a therapy delivery system, and further comprising:

means for delivering a therapy to the first heart chamber as a function of one or more of contractility and cardiac output of the first heart chamber.

44. The implantable medical device of Claim 42, further comprising means for adjusting the operation of the implantable medical device as a function of the determined distances between the first and second sonomicrometer crystals during a heart cycle.

45. An implantable medical device comprising a plurality of leads and an implantable medical device circuit enclosed within a hermetically sealed housing comprising:

a first endocardial lead bearing a first sonomicrometer crystal disposed through a venous pathway into a second heart chamber in association with the septum separating the first heart chamber from the second heart chamber, whereby the first sonomicrometer crystal is oriented toward but outside the first heart chamber;

a second endocardial lead bearing a second sonomicrometer crystal disposed through a venous pathway into a coronary vessel alongside the first heart chamber whereby the first and second sonomicrometer crystals are arranged in a vector extending through the first heart chamber;

means operable during one or more heart cycle for periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal;

means for determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal; and

means for deriving and storing data representing one or more of contractility and cardiac output of the first heart chamber from the determined distances in the implantable medical device.

46. The implantable medical device of Claim 45, wherein the implantable medical device comprises a therapy delivery system, and further comprising:

means for delivering a therapy to the first heart chamber as a function of one or more of contractility and cardiac output of the first heart chamber.

47. The implantable medical device of Claim 45, further comprising means for adjusting the operation of the implantable medical device as a function of the determined distances between the first and second sonomicrometer crystals during a heart cycle.

48. The apparatus of Claim 46, wherein the implantable medical device comprises an implantable pacing system, and further comprising:

a first pace/sense electrode on the first endocardial lead adapted to be disposed in operative relation to the second heart chamber;

a second pace/sense electrode on the second endocardial lead adapted to be disposed in operative relation to the first heart chamber;

means for delivering a pacing pulse to one of the first and second heart chambers; and

means for adjusting a parameter of the delivered pacing pulse as a function of the determined distances between the first and second sonomicrometer crystals during a heart cycle following delivery of the pacing pulse.

49. Apparatus for determining dimensional changes in the left ventricle due to mechanical movement of the left ventricle during the heart cycle comprising:

a first endocardial lead bearing a first sonomicrometer crystal disposed through a venous pathway with the first sonomicrometer crystal lodged within the right ventricle separated from the left ventricle by the septal wall;

a second endocardial lead bearing a second sonomicrometer crystal disposed through a venous pathway through the right atrium and the ostium of the coronary sinus such that the second sonomicrometer crystal is lodged within a coronary vessel in relation to the left ventricle, whereby the first and second sonomicrometer crystals are arranged in a vector through and across a substantial portion of the left ventricle;

means for periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal; and

means for determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal, whereby the mechanical motion of the left ventricle over the heart cycle can be determined without entering the left ventricle.

50. The apparatus of Claim 49, further comprising:

a third endocardial lead bearing a third sonomicrometer crystal disposed through a venous pathway with the third sonomicrometer crystal is lodged in relation to one of the right atrium or the left atrium;

means for periodically energizing one of the first, second and third sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other two of the first, second. and third sonomicrometer crystals to develop ultrasonic frequency sense signals; and

means for determining the distance between the at least one of the first and second sonomicrometer crystals and the third sonomicrometer crystal as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal, whereby the mechanical motion of the right atrium or the left atrium over the heart cycle can be determined.

51. Apparatus for determining dimensional changes of the atria comprising:

a right ventricular endocardial lead bearing a first sonomicrometer crystal disposed through a venous pathway with the first sonomicrometer crystal lodged within the right ventricle;

an atrial endocardial lead bearing a second sonomicrometer crystal disposed through a venous pathway with the second sonomicrometer crystal lodged in one of the right atrium or in the coronary sinus adjacent the left atrium, whereby the first and

second sonomicrometer crystals are arranged in a vector through the one of the right and left atrium;

means for periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal; and

means for determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal, whereby the mechanical motion of the atria can be determined.

52. Apparatus for pacing the right and left ventricles to alleviate symptoms of heart failure comprising:

a first lead bearing a first sonomicrometer crystal disposed at a first location of the heart outside the left ventricle;

a second lead bearing a second sonomicrometer crystal disposed at a second location of the heart outside the left ventricle, whereby the first and second locations define a vector across and through a substantial portion of the left ventricle;

means for repetitively timing a pacing escape interval establishing paced heart cycles:

means for delivering a first pacing pulse to one of the right and left ventricles at the time-out of each pacing escape interval and a second pacing pulse to the other of the right and left ventricles separated in time from the first pacing pulse by a pace delay;

means for periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal;

means for determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal, whereby the mechanical motion of the left ventricle over the heart cycle and cardiac output from the left ventricle can be assessed without entering the left ventricle; and

means for adjusting the pace delay to maximize the assessed cardiac output.

53. Apparatus for pacing the right and left ventricles to alleviate symptoms of heart failure comprising:

a first endocardial lead bearing a first sonomicrometer crystal and a first pace/sense electrode disposed through a venous pathway with the first sonomicrometer crystal lodged within the right ventricle separated from the left ventricle by the septal wall and the first pace/sense electrode situated for pacing the right ventricle;

a second endocardial lead bearing a second sonomicrometer crystal and a second pace/sense electrode disposed through a venous pathway through the right atrium and the ostium of the coronary sinus such that the second sonomicrometer crystal is lodged within a coronary vessel in relation to the left ventricle whereby the first and second sonomicrometer crystals are arranged in a vector through and across a substantial portion of the left ventricle and the second pace/sense electrode is situated for pacing the left ventricle;

means for repetitively timing a pacing escape interval establishing paced heart cycles:

means for delivering a first pacing pulse through one of the first pace/sense electrode and the second pace/sense electrode at the time-out of each pacing escape interval and a second pacing pulse to the other of the first pace/sense electrode and the second pace/sense electrode separated in time from the first pacing pulse by a pace delay;

means for periodically energizing one of the first and second sonomicrometer crystals to emit an ultrasonic frequency emitted signal that causes the other of the first and second sonomicrometer crystals to develop an ultrasonic frequency sense signal;

means for determining the distance between the first and second sonomicrometer crystals as a function of the time delay between emission of the emitted signal and sensing of the respective sense signal, whereby the mechanical motion of the left ventricle over the heart cycle and cardiac output from the left ventricle can be assessed without entering the left ventricle; and

means for adjusting the pace delay to maximize the assessed cardiac output of the left ventricle.

54. The apparatus of Claim 53, further comprising:

a third endocardial lead bearing a third sonomicrometer crystal and a third pace/sense electrode disposed through a venous pathway with the third sonomicrometer crystal lodged within the one of the right and left atria separated from the first and second sonomicrometer crystals and the third pace/sense electrode situated for pacing the one of the right and left atria;

means for timing the pacing escape interval as a successive V-A interval and AV delay;

delivering an atrial pace pulse through the third pace/sense electrode at the time-out of each V-A interval and the first and second pacing pulses at the time-out of the AV delay; and

adjusting the AV delay to maximize the assessed cardiac output.

55. A method of operating an implantable medical device (IMD), comprising:

positioning a first sonomicrometer crystal at a first location relative to a heart;

positioning a second sonomicrometer crystal at a second location relative to the heart;

determining the distance between the first and second sonomicrometer crystals; and

adjusting the operation of the IMD as a function of the determined distance.

56. The method of Claim 55, wherein the IMD comprises an implantable pacing system, and further comprising:

delivering a pacing pulse to the heart; and

adjusting a parameter of the delivered pacing pulse as a function of the determined distance.

57. The method of Claim 55, wherein the IMD comprises an implantable pacing system, and further comprising:

delivering a pacing pulse to the first heart chamber to elicit a contraction of the heart chamber:

determining whether a series of measured distances represents the contraction; and

adjusting a pacing energy of succeeding delivered pacing pulses to elicit the contraction upon delivery of each pacing pulse.

58. An apparatus for use in providing therapy to a heart, comprising:

a sensor to measure at least one distance measurement in the heart;

a delivery circuit coupled to the sensor to deliver a first pacing pulse to a first location in the heart, to deliver a second pacing pulse to a second location in the heart, and to control time of delivery of at least one of the first and second pacing pulses based on the at least one distance measurement.

59. The system of Claim 58, wherein the sensor comprises:

a first sonomicrometer crystal disposed at a first location of the heart; and

a second sonomicrometer crystal disposed at a second location of the heart.

60. The system of Claim 59, wherein the first and second sonomicrometer crystals are adapted for placement outside the left ventricle such that the first and second locations define a vector across a substantial portion of the left ventricle.

61. The system of Claim 58, and further comprising:

means to measure cardiac output of the heart; and

wherein the delivery circuit includes a circuit to adjust the time of delivery of at least one of the first and second pacing pulses to maximize cardiac output.